

# Hydrogen isotope retention in co-deposited Be layers

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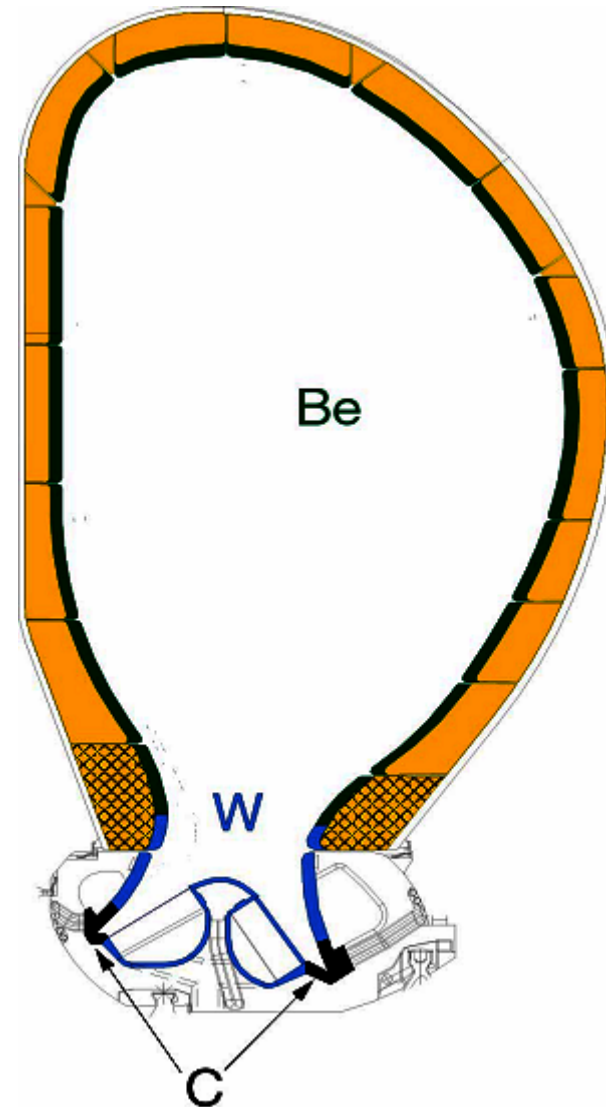


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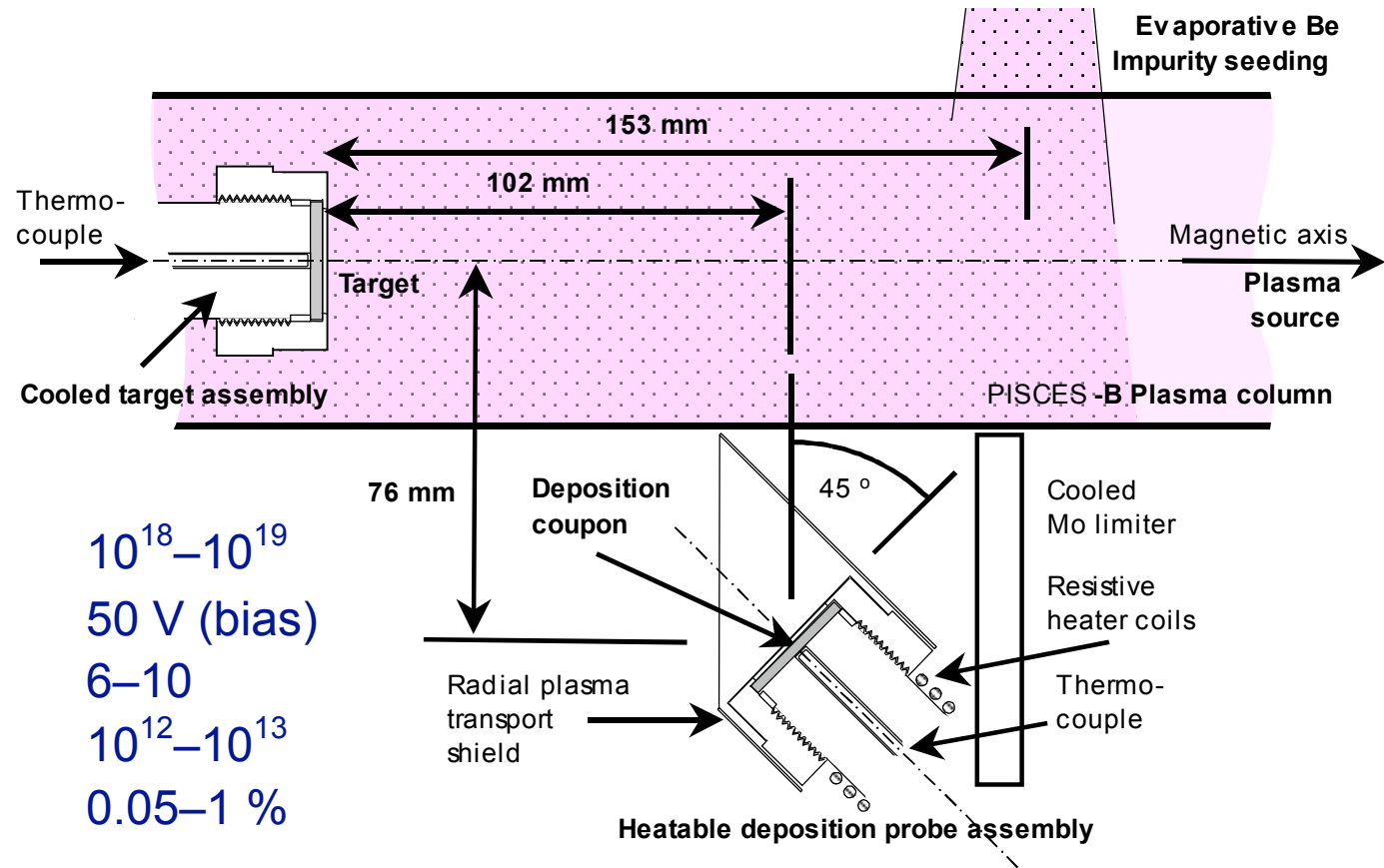
# Motivation

- UC San Diego PISCES and EFDA are investigating the influence of Be plasma impurities on exposed materials interactions relevant to ITER.
- The ITER design: Be first-wall, W divertor, C (graphite) strike points.
- Diverted plasma expected to be 'dirty': Eroded Be impurity conc. up to 10 %.



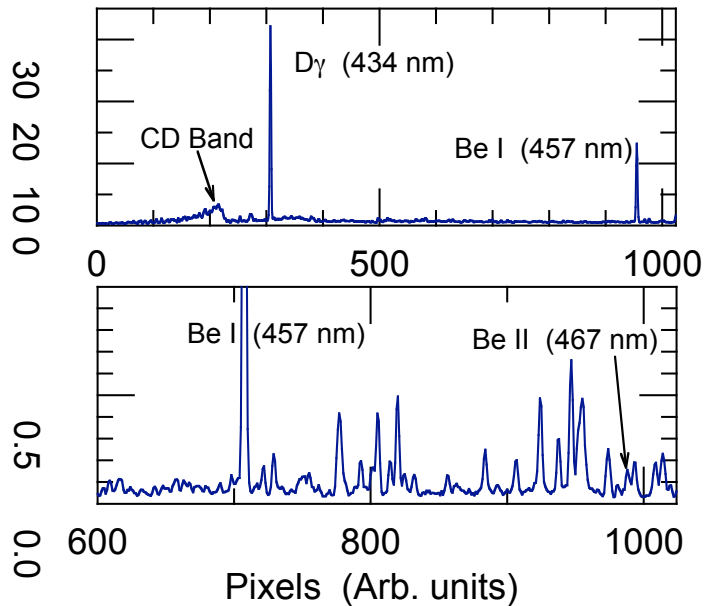
# PISCES-B simulates ITER divertor.

$\Gamma_{\text{ion}}$ ( $\text{cm}^2\text{s}^{-1}$ )	$10^{18}\text{--}10^{19}$
$E_{\text{ion}}$ (eV)	50 V (bias)
$T_e$ (eV)	6–10
$n_e$ ( $\text{cm}^{-3}$ )	$10^{12}\text{--}10^{13}$
Be fraction	0.05–1 %

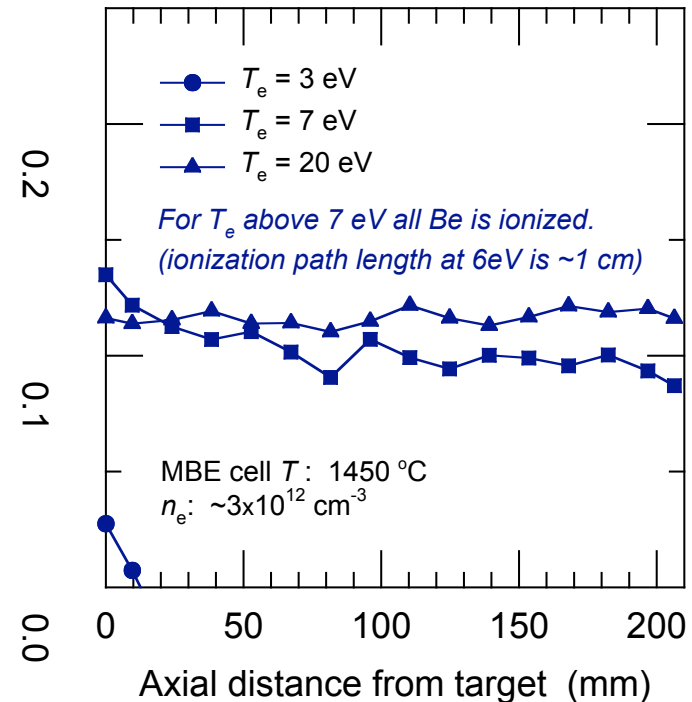


# OES is used to measure Be impurity concentration in the plasma

**Spectroscopic lines used to characterize Be seeding rate and target erosion**

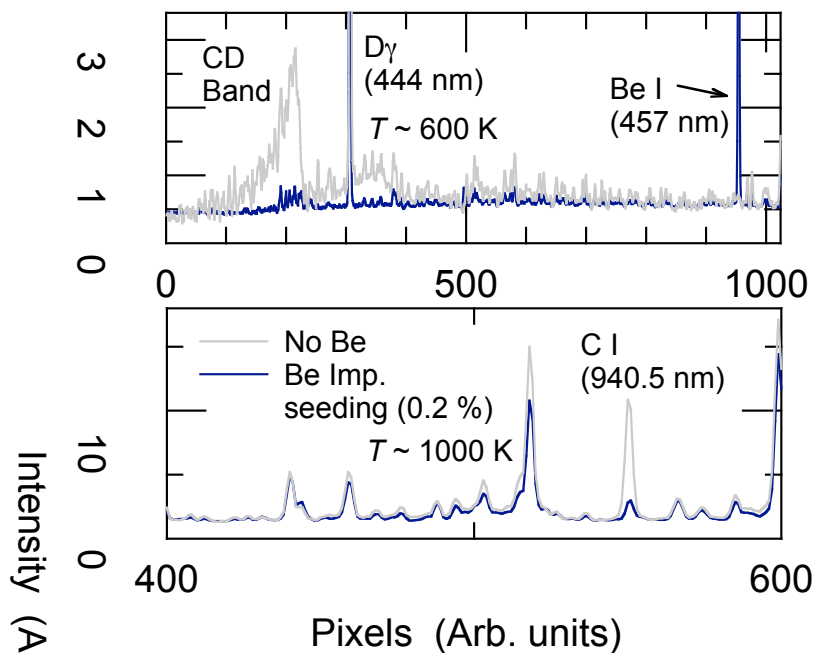


**Normalized Be impurity ion fraction in deuterium plasma as a function of  $T_e$ .**

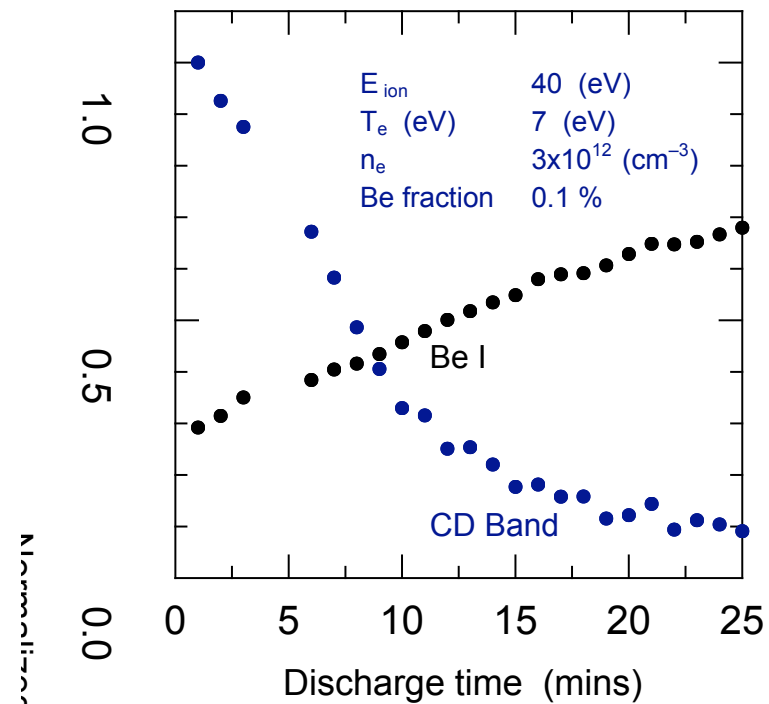


# As little as 0.1% Be produces significant changes in target PMI

*Chemical and physical erosion of ATJ graphite is reduced with Be Imp. seeding*



*Reduced chemical erosion & increased Be re-erosion*



# Be<sub>2</sub>C formation may be responsible for suppressed erosion

- The chemical & physical erosion of graphite is strongly suppressed by the formation of a Be rich surface layer
- Observations of significantly reduced target weight loss confirm OES data.
- Be Carbide sputter yield is low:  
(TRIMSP – 50 eV ions, 90° incidence)

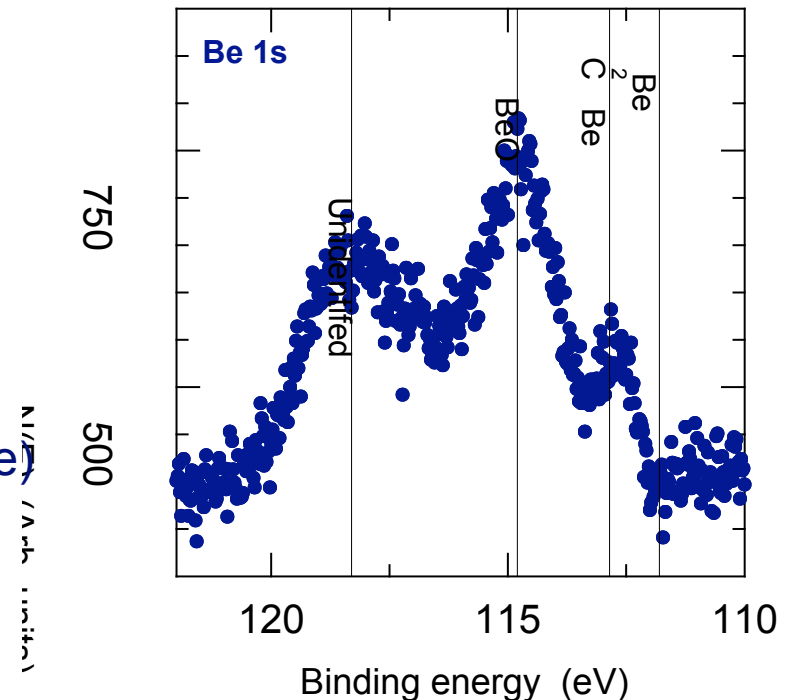
$$Y_{\text{Be}_2\text{C}} = 0.002$$

$$Y_{\text{Be}} = 0.02$$

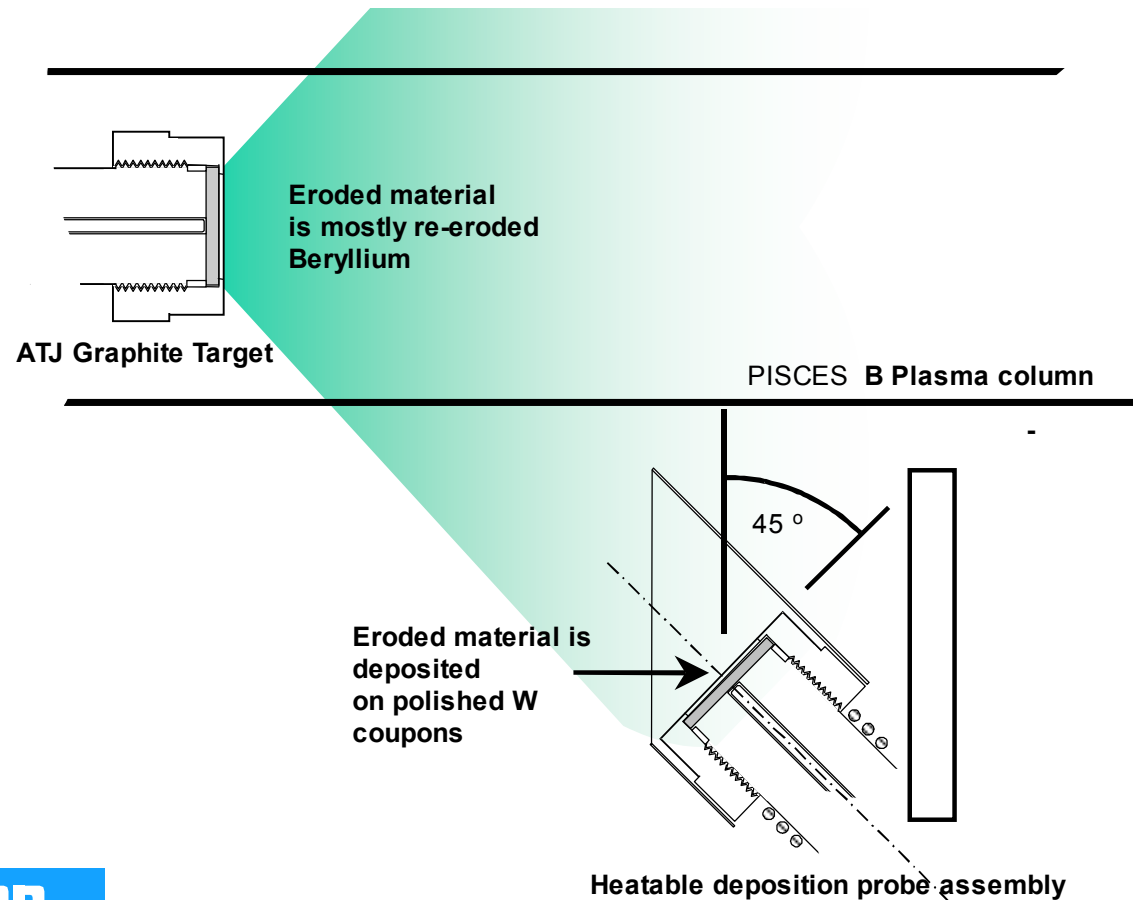
$$Y_{\text{C}} \sim 0.04$$



*XPS analysis reveals evidence for carbide formation*



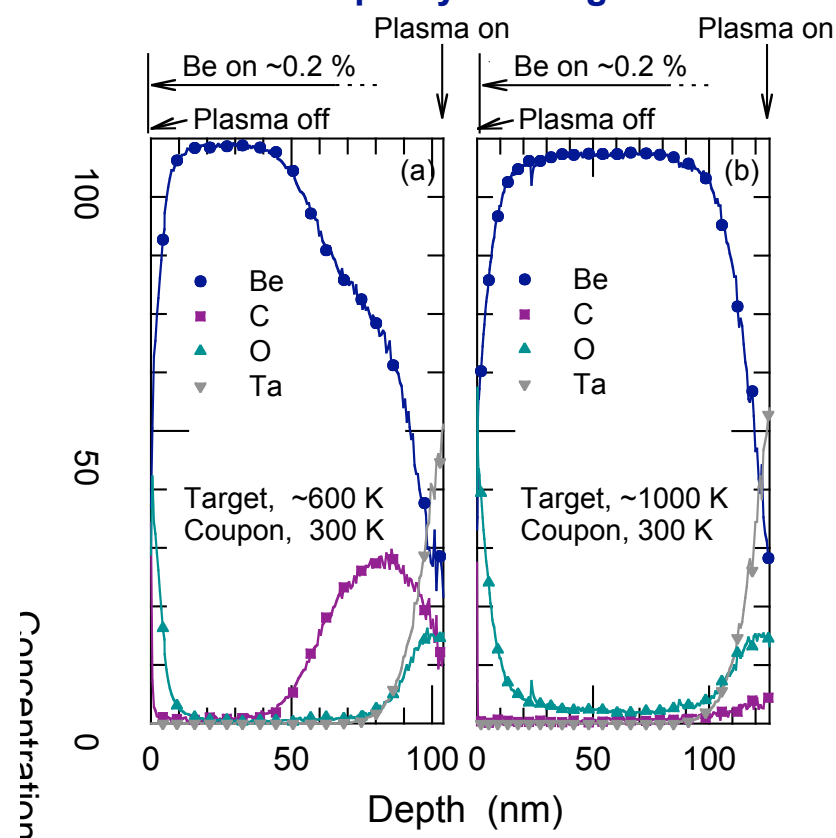
# Be dominates target PMI. What happens to deposits/co-deposits?



# Deposited material is Be rich

- XPS profiling provides deposited layer thickness and composition.
- Deposits have low C content (<3 at. %) once target erosion is suppressed.
- O content <3 at. % for RT deposition, but ~30 at. % as the probe temperature was increased up to 573 K.

Deposited layers are Be rich. C deposition is reduced when Be impurity seeding is active.

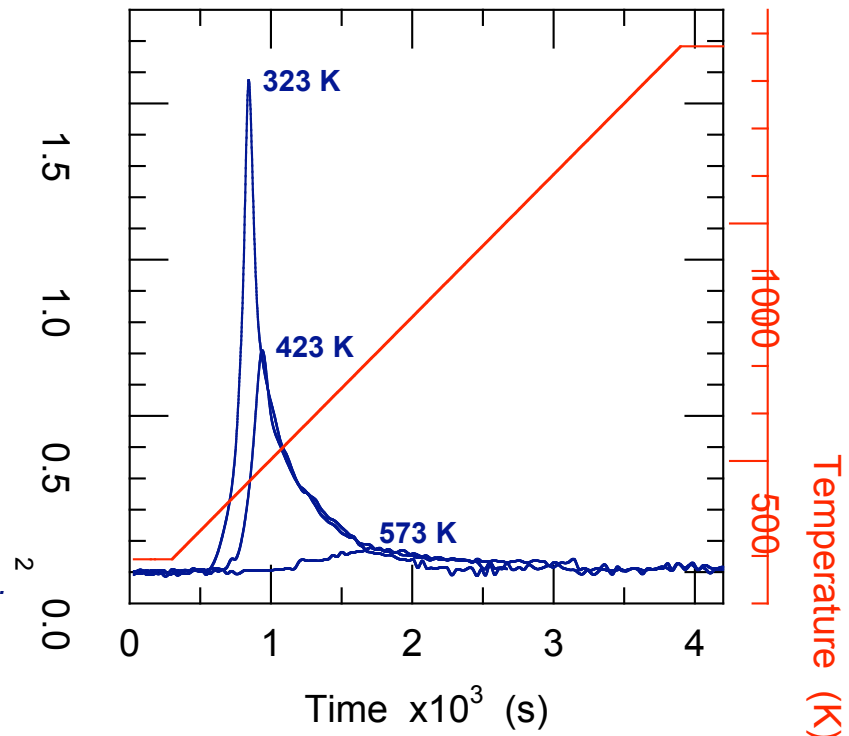




# Retention in deposits depends on coupon surface temperature

- $D_2$  is the most significant deuterium species released.
- Retention decreases as coupon temperature increases.
- TDS profiles are unlike desorption from co-deposits of BeO  
(Markin et al. *J. Nucl. Mater.* 283-7, (2000) 1094),  
or implanted beryllium  
(Causey et al., *Fusion Eng. Des.* 61-2, (2002) 525).

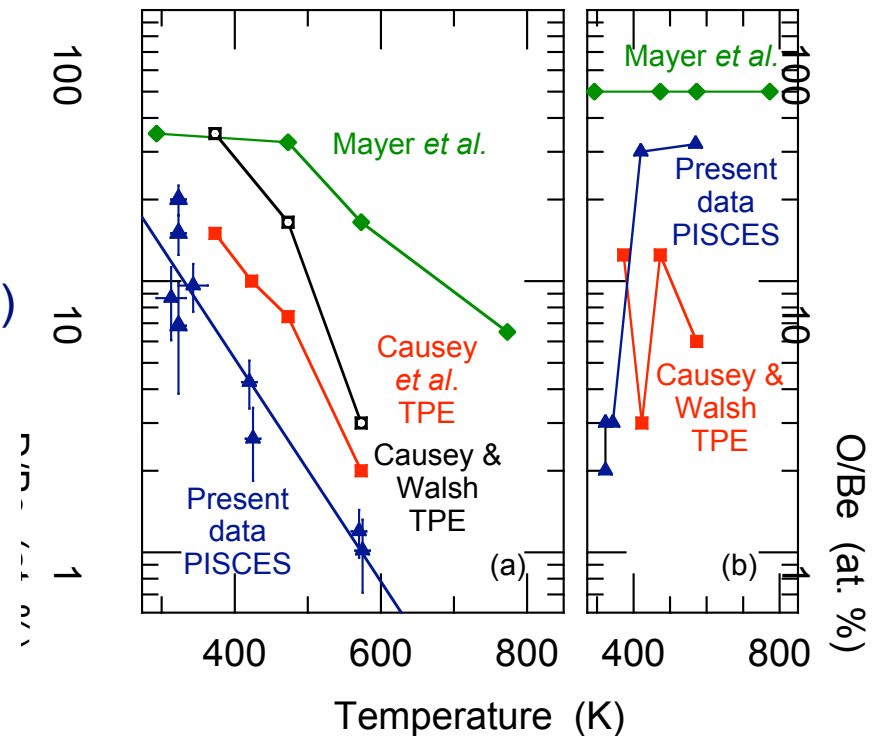
Retained deuterium in co-deposited layers is reduced at higher collection temperatures



# Comparison with literature

- PISCES co-deposits have lowest D/Be ratios despite high O/Be values at higher temperature collection
- Incident species mix (Be, O, D, ..) during collection is sure to be a key parameter.
- Further work is underway to investigate this.

D/Be and O/Be  
PISCES and similar work in the literature

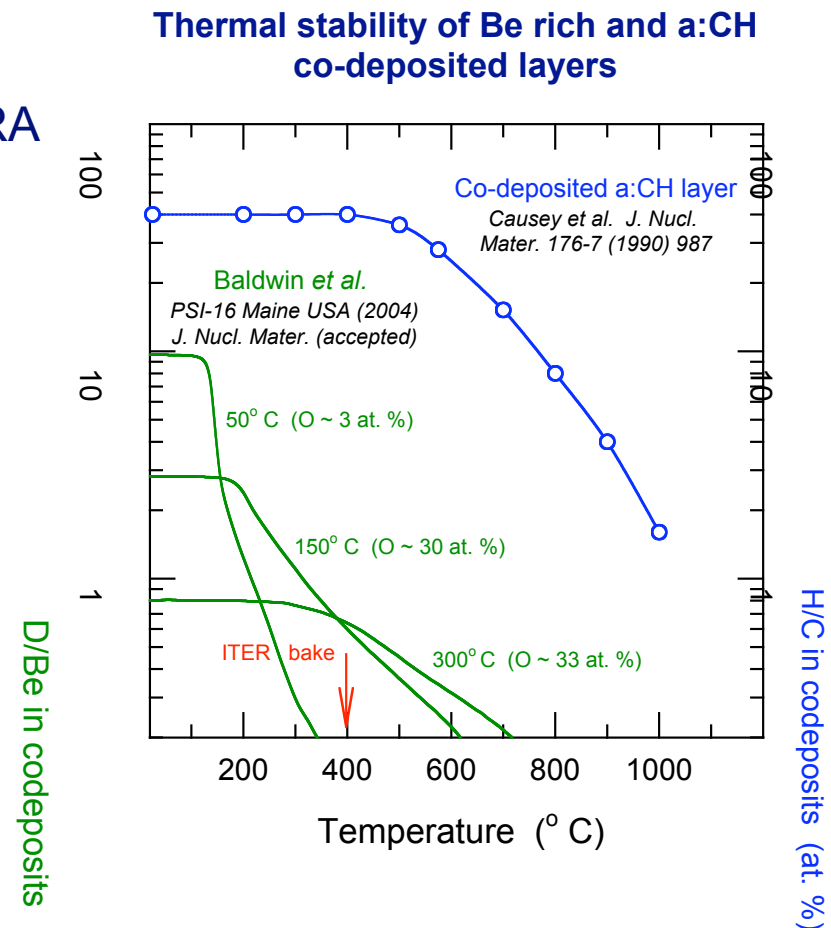


Mayer, *et al.*, *J. Nucl. Mater.*, 230 (1996) 67, Causey & Walsh, *J. Nucl. Mater.* 254, (1998) 84  
Causey *et al.*, *Int. Workshop on Tritium Material Interaction Studies, July 18–19, (1996), Japan*

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# Be rich co-deposits are less thermally stable than a:CH films

- Desorption contours are produced from TDS profiles
- TDS retention values agree with NRA
- Inventory is reduced in co-deposits formed on higher temperature surfaces. But, higher temperature co-deposits are more resistant to inventory desorption.
- Be rich co-deposits have less H isotope inventory, and are more easily desorbed than a:CH.
- Co-deposited layer structure, O content, or both may influence desorption kinetics.



# Summary

- Small Be impurity levels (as low as ~0.1 %) strongly suppresses the erosion of graphite at the temperatures explored (up to 1000°C).
- A Be rich layer, with a carbide component, forms rapidly on the target and leads to Be rich co-deposits within line-of-sight locations.
- H isotope retention in co-deposits is less efficient on hotter surfaces. However, the trapping mechanism, the role of impurities and dependence on the incident species mix are not yet clear.
- Results suggest (assuming these layers form in ITER) that co-deposited H isotope inventory can be substantially reduced by divertor baking or operation at temperatures above 350° C.
- Experiments are underway utilizing CD<sub>4</sub> and O<sub>2</sub> puffing to make connections with observations in JET and to understand the role the O<sub>2</sub> plays.

